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AERO-ENGINES

INSPECTION OF BEFORE FLIGHT

"C" LICENCE

The Air Ministry, whilst accepting no responsibility for the contents of this book, recognizes it as a textbook that should prove to be of value to intending applicants for Ground Engineers' licences

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INSPECTION OF AERO-ENGINES BEFORE FLIGHT

By R. F. BARLOW

GROUND ENGINEERS' CATEGORY "C" LICENCE

THE AIR NAVIGATION DIRECTIONS

THE duties of a ground engineer licensed in Category "C" comprise carrying out top overhauls and repairs, installing and maintaining those types of engines covered by his licence, and the certification of such work in the approved manner.

The requirements of the British Government regarding the manufacture, maintenance, and operation of Civil Aircraft holding a British Certificate of Airworthiness are contained in the Air Navigation Directions (A.N.D.) which are issued by the Secretary of State for Air, under Article 30 of the Air Navigation (Consolidated) Order, 1923, and can be purchased from His Majesty's Stationery Office.

It is a condition of the issue of a licence that the candidate shall be thoroughly conversant with these directions, particularly with those sections dealing with the issue of licences, the maintenance of aircraft, the maintenance of records, and the certification of all work carried out by or under the supervision of a ground engineer. New candidates must therefore be prepared to be cross-examined on their knowledge of these Directions, as a preliminary to the technical examination, and a lack of knowledge of this subject may adversely influence the recommendations of the board of examiners.

Before presenting themselves for the first time, candidates are therefore strongly recommended to make a close study of these Directions, paying particular attention to the following sections—

Section II. This section deals exclusively with the manufacture of aircraft. (NOTE. The term "Aircraft" referred to throughout the Directions is to be regarded as a general one only, and is intended to cover not only the air-frame, but also aero-engines, instruments, and all other accessories.) It may on that account appear to be of no interest to the ground engineer concerned in repair and maintenance only. Some knowledge of this section is, however, of value, since a better appreciation of the method of control of the manufacture of aircraft in this country may be gained therefrom, which in turn will result in the candidate understanding the reason for, and value of, the documents which accompany that control and without which a ground engineer is not permitted to accept or to fit spare parts.

For the benefit of those not fully conversant with the system in operation, it may be explained that while the Director of Aircraft Inspection, as representing the Secretary of State for Air, is *the* authority on all matters pertaining to the inspection of Civil Aircraft, the Air Navigation Directions

impose on all manufacturers of aircraft and accessory parts thereof the need for maintaining an efficient inspection staff who are responsible for ensuring, by suitable testing, that all materials used in the construction of such aircraft and accessory parts are in accordance with specification requirements, and that all parts are strictly in accordance with the drawings and/or specifications that have been approved by the Air Ministry.

Firms whose inspection organization meet these conditions are "approved" by the Air Ministry, and their work is supervised by the Director of Aircraft Inspection (A.I.D.). Such "approvals" are not confined to constructors of complete aircraft, aero-engines, etc.; but are also issued to firms producing raw material, stampings, forgings, and in fact to all subsidiary processes connected with the manufacture of aircraft.

Firms so "approved" are authorized to "release" and to issue "release notes," covering raw material, the finished product, etc., according to the terms of their approval.

In order to safeguard against the release of materials, etc., by unauthorized persons, it is required that all release notes shall bear a certificate in the following form—

> "I hereby certify that the whole of this material and/or parts, covered by this advice note, have been inspected and tested and conform with specification —— and drawings relative thereto in accordance with the conditions of the A.N.D."

The Certificate must be signed by a responsible member of the firm by whom the advice note is issued. In addition the document must quote the Air Ministry Authority under which it is issued. This authority takes one of two forms—

(i) A series of six figures followed by two, e.g. 123456/30, or
(ii) A.I.D./1068/33/Leeds Office.

It should be noted that release or advice notes are not issued in the case of complete aircraft or complete engines. In the former case the "Certificate of Airworthiness" meets all the requirements in this respect, while in the latter case, "release" is covered by the certificate contained in the engine log book.

Section III. Explains the terms and conditions under which licences are issued, and new candidates should study these conditions before sending in their applications in order to satisfy themselves that they have the required qualifications and have reasonable prospects of passing the examination (which is an oral one). This will prevent disappointment and loss of time and money in respect of fees and travelling expenses, which are not recoverable under any conditions.

Section IV. Is a particularly important one for the ground engineer as it contains details of, and instructions in the preparation of daily certificates of safety for flight, without which no aircraft plying for hire and award may fly.

The preparation of, or at least the signature of these certificates constitutes an important part of the duties of a ground engineer, and new candidates are advised to study the terms in which the certificates are drawn up, since they emphasize the responsibilities of the signatories.

The certificates are only valid for a period of twenty-four hours, hence the reference to them as "daily" certificates.

Section V. Deals with the repair, overhaul, and the embodiment of modifications. It also gives the form of certificate that must be prepared following such work being carried out.

Regarding modifications, all approved alterations or modifications to aircraft, aero-engines, etc., that in any way affect the safety of the aircraft

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are notified by the Air Ministry by means of "Notices to Aircraft Owners and Ground Engineers," which are issued gratis to all registered owners of aircraft and persons holding a ground engineer's licence.

It will be noted that these notices invariably quote a date by which the modification with which they deal must be embodied, failing which a renewal of the certificate of airworthiness of any aircraft concerned will be refused.

It is of importance, therefore, for ground engineers to pay close attention to these notices, since failure to embody all relevant modifications in the aircraft for which they are responsible will be recorded against them. A second lapse of a similar nature would probably result in their licence being withdrawn.

A complete set of these notices in force at the time a licence is first issued is forwarded with the licence, and it is a sound plan to analyse these carefully and tabulate those concerned under the engines included in the licence held. These tables will form a reliable and readily accessible record from which to check a particular engine under examination for the first time.

No matter how familiar one may be with an engine, there is always the possibility of having the attention diverted during the process of final checking, which very often results in some points being overlooked.

In addition, certain desirable modifications, which have been approved by the Air Ministry, are introduced from time to time. These are notified to the owners by the authority responsible for recommending the renewal of the Certificate of Airworthiness. While the issue of that certificate is not affected by the inclusion or omission of this class of modification, they should, wherever practical, be embodied at the earliest opportunity.

Section VIII. Is of importance since it amplifies the details, given in Section II (*d*), of the list of instruments that are required to be fitted under varying conditions of operation of an aircraft.

When checking off the installation of the engine(s) of a machine not previously certified by him, the ground engineer must satisfy himself that the instruments fitted are in accordance with the requirements of this section and that they function correctly.

Section X. Deals with the preparation and maintenance of Log Books. The "C" Licensee is only responsible for the maintenance of the engine log book (C.A. form 28) and in it must be entered particulars of all running by the engine for which it has been issued, together with a complete history, chronologically arranged, of all adjustments, repairs, and replacements made to or on the engine, and all authorized modifications embodied. The daily and other periodic examinations made must also be recorded, and all entries certified by the ground engineer by whom, or under whose supervision, such work was carried out.

All entries must be clear, concise, and written in ink.

The pages of the log book on the left hand side are ruled for the entry of dates, the speed at which the engine was run, duration of running, and times run since last top and last complete overhaul. The right hand pages are for the entry of particulars of adjustments made and the details of replacements and overhauls.

All entries are required to be made within twenty-four hours of the events to which they refer—in practice they should be made the same day as a particular job is completed.

AIRWORTHINESS HANDBOOK FOR CIVIL AVIATION

Another publication with which all ground engineers must be familiar is the *Airworthiness Handbook for Civil Aviation*, Air Publication 1208

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(herein referred to as A.P. 1208), also obtainable from His Majesty's Stationery Office.

The handbook supplements and amplifies the requirements, both technical and legal, of the Air Navigation Directions. It is published in the form of a series of leaflets dealing with design, manufacture, safety requirements, inspection, etc.

Additions and amendments to this handbook are notified periodically by means of a notice to aircraft owners and ground engineers.

Many of the leaflets are admittedly of small value to the average ground engineer, but a large percentage are of vital interest and concern, and their contents must be thoroughly understood by him.

TECHNICAL KNOWLEDGE REQUIRED BY CANDIDATES

The details of the technical knowledge required for a "C" licence are briefly set out in the Air Ministry pamphlet No. 34. A copy of this pamphlet is forwarded with the official application form to all new candidates, and it is on this pamphlet that candidates will eventually be examined by the Board of Examiners at the Air Ministry.

It should here be noted that "C" licences are not issued to cover all types of engines, but only such named types of which the candidate has proved to the satisfaction of the Board that he possesses the necessary experience. Exception to this will only be made in very special cases, e.g. if a candidate should satisfy the Board that he has a very sound and thorough knowledge of the principal types of modern radial engines and has also had a fair experience of one or two types of the small 4-cylinder vertical engines, he might be recommended for a licence to cover "all air-cooled engines," but it must be again emphasized that such a recommendation is exceptional.

New candidates are strongly advised, when completing the official application forms, to review carefully their experience and only include those engines upon which they are certain they can satisfy the examining board. They will be given every opportunity during the examination of amplifying the statements made in the application form, and they are advised to omit any reference to engines on which they have had only limited experience until they appear before the board and trust to the mature judgment of the latter to make their recommendations as wide as possible.

By adopting this method the candidate will inspire greater confidence in the board, who will in consequence give him more sympathetic consideration than they would to one who assumes to have a wider knowledge of the subject than his examination proves to be the case.

The subjects will now be dealt with in the same order as they appear in the pamphlet (A.M. 34).

(*I*) *Knowledge of the general construction of the particular type or types of engine for which the licence is required, together with the running permissible before overhaul. The method of carrying out top-overhaul, allowances for wear and distortion. The methods of inspection and testing during and after top-overhaul to ensure correct assembly and functioning.*

Candidates must be able briefly to describe the essential details of construction of the engine(s) he desires to have included in his licence, referring to any special features in design and/or construction—e.g. any features which entail unusual methods of fitting, assembly, or maintenance. He must also be able to describe, and, if required to do so, roughly to sketch the lubricating systems of each and every engine, from the tank (or sump) through the whole system and engine back to the tank (or sump), also the method of lubricating all parts supplied from an external source.

He must also satisfy the board on having had the necessary experience, both in the workshop and on the aerodrome, on general workshop processes and in the repair and maintenance of the engine(s), and that he is familiar with the recognized maximum period it is safe to run the engine(s) between the top and complete overhauls.

In this connection candidates are reminded that the ground engineer is solely responsible at all times for determining when an engine requires attention and the amount of work to be done and replacements necessary to maintain it in an airworthy condition. Engine makers invariably recommend maximum periods for both top and complete overhauls and these periods should not be exceeded to any appreciable extent unless the ground engineer is quite satisfied from the general running of the engine that the times so recommended can be exceeded with safety. In permitting such an extension he must make quite certain that revolutions, oil pressure, consumption, and all other indications as recorded in the log book are beyond suspicion and justify his decision.

Should he permit an extension, or should he in fact allow the engine to run at any time when the log book entries indicate that the engine is not maintaining power or is otherwise in an unsatisfactory condition either internally or externally, he is liable to be severely censured by his supervising authority, and any repetition of this failing would most probably result in the cancellation of his licence.

The method of carrying out a top-overhaul involves the question of the extent to which a "C" man may dismantle an engine and the operations he may undertake. Generally speaking, it is taken that he may dismantle an engine as far as possible without disturbing the crankcase joint, or interfering in any way with the main and big-end bearings. For the rest he is permitted to carry out minor repairs and/or to replace any part found to be worn or damaged providing that such parts are obtained from an approved source, duly covered by the necessary documents as laid down in Section II and Section V of the A.N.D.

The extent of dismantling of magnetos is also limited, and is confined to taking down distributors, contact breakers, brushes, etc., and the cleaning, adjusting and/or replacement of these, or parts thereof.

The candidate must also be able from experience to detail the main points where defects may develop and his method of rectifying same. He must be able to express in general terms the allowances that may be made for wear and distortion. On this point candidates are not expected to be able to recite to the last thousandth of an inch the engine makers' recommendation for a particular dimension. He must, however, satisfy the board that he possesses either a copy of the engine makers' handbook containing this information, or his own notebooks in which these particulars are detailed.

Systematic reference to a reliable note or handbook will invariably result in a more satisfactory job than trusting to memory.

The inspection and testing referred to in this paragraph of the syllabus relate to individual components and not to the completed engine. They include pressure testing water-jackets and other parts of water-cooled engines; air pressure of induction systems and the rectification of faults found; testing the bores of cylinders, pistons, etc., for ovality and/or distortion; testing gudgeon pins, bores of pistons, and small end of connecting rods for parallelism and alignment; testing valves, after grinding in, for being gas-tight, etc., etc., besides a thorough and minute examination of every part as they are built up to ensure correct assembly.

(*II*) *Knowledge of the methods of examining and testing the correct erection of the power plant and its accessories in the aircraft, including*

the fuel, oil, cooling, ignition, induction and exhaust systems, tanks and pipe lines, engine controls, airscrew complete with hub, together with characteristic defects.

It must be realized that the work covered by the "A" and the "C" licence overlaps when installing an engine in the air-frame. Although it is fundamentally the duty of the "A" man to ensure that the engine bearers are true and in accordance with rigging instructions it is also the responsibility of the "C" man to ensure that this has been done before he attempts to install the engine.

He is also responsible for all services to the engine, including tanks and pipe lines for fuel, oil and water, and for ensuring that the supply from these is requisite for the engine's requirements, that all engine controls, including those for magneto and throttle, function correctly, are free of excessive backlash, and well lubricated.

He must also ensure that all ignition wiring and switches are sound and function satisfactorily, that the induction and exhaust systems are correctly assembled and properly stayed, and all joints gas tight. The assembly of the airscrew to its hub and the fit of the hub on the airscrew shaft are also the responsibility of the "C" man.

(III) Knowledge of the inspection, adjustment, and testing of the power plant and its accessories to ensure correct functioning and power output after installation in the aircraft and during daily maintenance including airscrews, magnetos, carburettors, pumps, filters, engine starters, and starting mechanism and other parts or components on whose condition the correct functioning of the power plant depends.

Regarding the testing of engines after top-overhaul, while some form of variable torque dynamometer is preferable such apparatus is not always available. Recourse has therefore to be made to a test or calibrated airscrew. The use of the ordinary flight airscrew for testing is not satisfactory for the reasons given further on in this book in the section dealing with engine testing.

A candidate will be required to show that he has a practical knowledge of the principles of tuning up, and to describe the principal defects arising from faulty carburation, incorrect magneto timing, also the evidence and method of tracing and remedying defects in all accessories with which an engine may be fitted.

He will also be required to outline in some detail the normal routine inspection he would subject an engine to, calling on his experience where he has found some peculiarity on a particular type of engine that calls for more than ordinary attention.

Where starters are fitted, he must know what type or types have been approved for a particular engine, and be able to describe their functioning and method of testing. He must also be familiar with any types of auxiliary pumps and similar accessories that have been approved for a particular engine.

(IV) Knowledge of the methods of inspecting and testing the installation of the instruments connected with the power plant concerned, to ensure correct functioning, including pressure gauges, temperature and revolution indicators, boost gauges, and tank contents gauges.

Candidates must have a general knowledge of the construction, functioning, and installation of the instruments referred to above. While some knowledge of the methods of testing as applied in the laboratories of the instrument makers is an advantage, it is not essential, since the candidate is unlikely to have the elaborate plant at his disposal necessary to carry out such work. He is therefore limited to comparing the performance of a

doubtful instrument against one of known accuracy. A candidate must, however, be familiar with all the special requirements and precautions necessary when installing these instruments.

(V) For licences to include supercharged engines, a knowledge of the functioning of superchargers and boost control is required.

As is indicated from the wording of the syllabus, this subject is only taken where the engines required to be included in the licence are of the supercharged type.

To be successful, the candidate must give proof of having a detailed knowledge of the principles of supercharging, the construction of the particular supercharger and the methods of testing an engine so fitted, and it is also desirable that he has a knowledge of the special test equipment which is necessary.

He is required to have a knowledge of the method of control and adjustment of boost pressures and of setting and adjusting the throttle and gate control during the installation of the engine in the machine.

(VI) For licences to include compression ignition engines, a knowledge of fuel injection systems and methods of regulation is required.

This also is a special subject and examinations at the present time are largely confined to named types of engines only, but a general knowledge of the principles of compression ignition with some knowledge of the fuels used and the method of starting are essential.

In conclusion of this part new candidates may rest assured that the examination will be confined normally to practical points and subjects only. A working ground engineer is not expected to be fully conversant with either aerodynamics or the theory of internal combustion engines. His job is to repair and maintain, not to design, although at the same time some sound knowledge of theory frequently assists in solving practical problems.

PRACTICAL HINTS ON OVERHAULING, INSTALLING, AND MAINTAINING AERO-ENGINES, AND OTHER POINTS COVERED BY GROUND ENGINEERS' LICENCES IN CATEGORY "C"

1. REPAIR AND OVERHAUL

Cylinder Heads (Air-cooled Engines)

These components require very special attention, particularly where made of cast aluminium alloy with valve seatings of bronze or steel, either pressed, cast, screwed and/or expanded into the head casting. These seatings have a tendency to work loose and a constant watch must be made for the first evidence of this happening. They must, therefore, be tested whenever the head is removed. There are several ways of testing—e.g. a light tap on the under-side (care being taken not to bruise the seat face) will, if the seating has started to loosen, result in an oil stain appearing in the carbon at the joint between the seating and the head. (This test must, of course, be carried out before decarbonizing.) An even more searching test can be made when testing the effectiveness of the valve grinding operation referred to later.

The defect is one that develops fairly rapidly once it has started, and unless attended to immediately will most probably result in a serious breakdown of the engine.

The only remedy is to fit a new oversize seating. This, as a general rule

can only be carried out by the engine makers, who alone have the necessary special tools that are essential.

Some designs also include inserted bronze sparking plug bosses. These must be watched and treated in precisely the same way as the valve seatings and must be regarded as of equal importance owing to the dangers of air leaks and consequent overheating.

After thoroughly cleaning all over, examine for cracks, particularly around the inlet and exhaust parts, bosses for holding down bolts, valve rocker brackets where cast integral with the head or of the webs supporting the platforms or other seating where the brackets are separate.

Should any of the fins be cracked or broken, an effort should be made in the former case to localize by drilling a small hole at the end of the crack. If impossible owing to position, it is better to break away a small portion of the fin and smooth up the edge. The removal of a small portion of one or two fins will not seriously affect the efficiency of the cooling.

Examine all the jointing faces and/or spigot joint to cylinder for distortion, true up where necessary.

Examine all studs for fit of thread in the head; any that are found to be at all slack must be replaced by ones having oversized threads.

Examine valve guides for wear especially for being excessively bell mouthed at either end and/or burnt at the inner or combustion chamber end.

Replace where necessary, using proper tools, if only of the bolt and tube type. On reamering out the bore of the new guide, make sure that the reamer is truly square with the valve seat.

(NOTE. Where a new guide has been fitted, it is a good plan to use a little plumbago and oil as a lubricant on assembly. This will prevent any tendency to "picking up.")

If the valve seat requires re-cutting, ensure that the cutter is square with the valve guide.

Where there is any pocketing resulting from the valve having hammered into the seating, the ridge must be removed by blending the seating, using a rose cutter having a greater cutting angle than that of the valve seat. Unless this is done, the sharp edge made by the pocket will eventually cause pre-ignition, with all its attendant evils of overheating, burnt valves, etc.

When grinding in valves on to bronze seatings, use a very fine grinding medium. The ordinary paste is liable to cause circumferential grooves which frequently can only be removed by recutting the seat. Even with a fine medium, pressure at first, and until the "edge" has been taken off the grinding medium, must be very light.

Finish with metal polish to get a really first-class joint.

To test, assemble valve with springs, etc., and pour a small quantity of petrol through the port on to the top face of valve and examine the underface. A little chalk rubbed on the seating will assist in showing up any tendency for the petrol to percolate through. Incidentally this test, where the head is of the type referred to previously, will also show up any slight tendency for the valve seating to start loosening. Avoid the obvious error of mistaking one defect for the other.

Examine all parts of the valve rocker mechanism. Where adjustable pads are fitted in the end of the rocker—they are generally case-hardened—ensure that they are not cracked, that there are no flats or that they have not worn through the "case" and are in consequence soft. Where the rockers are operated by push rods through a ball joint see that the wear in the socket is even and is not causing binding at any point in the cycle of operation.

Thoroughly examine the brackets supporting the valve rockers for cracks and excessive wear. In particular see that the fulcrum pins are a good tight fit in the bracket and have no excessive clearance in the rocker, or *vice versa*, where the pins fit into rockers and float in the brackets.

Cylinders (Air-cooled Engines)

Until a few years ago, cast iron cylinders were fairly common on the smaller low-powered engines. Such cylinders require special attention, since they are liable to develop cracks in the fins, and should be examined very closely for this defect.

The only remedy that can be applied is that referred to above under Cylinder Heads.

On more modern engines of this type and on the larger engines steel cylinders with the fins machined from the solid are invariably fitted. Apart from mechanical damage, and the possibility of cracks developing from bad machining at the root of the fins, few troubles should be experienced.

Examine all joint faces and remove all bruises, at the same time maintaining true surfaces. Examine bores for scores, uneven wear, including ovality. Where scores are not too deep, remove by light lapping, but where this is impracticable, they must be returned to the makers or other works where they have the necessary facilities for regrinding.

Cylinders (Water-cooled Engines)

Most modern water-cooled engines are fitted with cylinders of the mono block type with the water jackets cast in a light alloy, and steel liners pressed or screwed in or located by some special form of jointing.

There are still in service, however, types of engines in which the water jacket of each separate cylinder is built up from steel sheet.

Water leaks are probably the greatest of the troubles experienced on these components and each type of cylinder requires different treatment in remedying the defect.

Leaks due to corrosion of the liner are less frequent in the more modern engines due to the liners being treated before assembly by nickel deposition or other protective methods. On the older types, however, this was a very real difficulty, and in the case of those with built up steel jackets resulted in scrapping the entire cylinder.

The repair of leaks in the jacket is more simple. In the case of the cast jacket plugging is the best method, while with the built up steel jackets the trouble can be overcome by sweating a small piece of light gauge sheet brass or copper over the defect. Great care must, however, be exercised in carrying out this operation in order to avoid distortion, and only a reasonably light tinman's soldering iron should be used for this purpose. Under no circumstances use a blow lamp, however small in power, as irreparable cracking of the water jacket is likely to result from stresses set up in the metal from local overheating. For this reason welding or brazing must not be attempted.

Water leaks may also develop in the joint between the liner and the cast jacket which necessitates in many cases a fair amount of dismantling in order to remedy the defect. Care is necessary during reassembly to ensure correct alignment of all parts and to avoid distortion which may impose undue stress in the jacket or adjacent parts.

The whole of the water cooling system should be tested at every overhaul. The pressures to be used and the exact method of carrying out the test vary to some extent with different types of engines. In general they include a test with hot water at a pressure up to 40 lb. to the square inch,

followed immediately by a similar test using cold water. The makers' instructions in this respect, however, must be strictly followed in every case.

Examination of the valves, etc., will be made in the same way as on air-cooled engines, but the design of the valve gear invariably includes a camshaft running the entire length of a cylinder block and in some designs two or more blocks. Bearings for the camshaft may form an integral part of the cylinder head or may be mounted in a separate case, which in turn is mounted over the cylinders.

In the latter type great care is necessary in lining up the bearing face(s) on which the camshaft casing is carried, and any low points must, where the design permits, be made up by inserting shims of the requisite thickness or by truing up as the case may be. The under-face of the case must also be checked and trued up where necessary.

Failure to observe these precautions will probably result in a failure of the cam casing due to the development of cracks.

The lubricating system also calls for special attention, all oil holes and channels must be cleaned and examined to ensure that all parts of the cam and valve gear are properly lubricated.

Examine all cams for wear and remove any scores by light stoning. If flats are found in any of the cams test with a smooth file to ensure that wear has not progressed through the hardened surface. Replacement of the entire camshaft is the only cure for this defect, but if still hard, stone down any ridges formed adjacent to the flats to ensure smooth working of the valve gear.

Examine all studs for damaged threads and also for slackness in the housing. In the latter case replace with studs having oversize threads on the end fitting into the housing.

All gears must be examined for wear and damage and adjusted to give the clearance and backlash recommended by the makers.

Examine all splines or other method of joining up the sections of the cam driving shafts. Replace where excessive wear or damage is found. Smooth out any sharp nicks which may lead to the development of cracks.

Valves

Remove all carbon, and examine stems, grooves or thread for the spring retaining collets or valve ends. On some engines the makers call for special fits at this point; ensure that these requirements are met. Examine the valve end for wear. Many modern designs include a detachable valve end which makes replacement for wear a simple matter, but where no such provision is made the end of the valve must be dressed up where necessary in order to present a true face for the valve operating gear. The seat of the valve calls for minute examination for cracks, in addition to evidence of burning. Cracks may also be present at the base of the stem where the latter blends into the head. Lightly polish out any scores on the stem.

Valve Springs

Clean and examine all over for signs of cracks and at the ends for uneven wear and for damage.

Check for tension or rate of loading and for "free" length. Failing better facilities a good idea of tension can be obtained by compressing a new and a worn spring by hand. Any serious difference will be readily noted. For "free" length also compare with an unused spring where the drawing dimension is not known.

Pistons

Clean the carbon from the crown, ring-grooves, particularly at the back of the latter, all oil holes and inside of the crown. When cleaning the ring grooves be careful not to damage the sides or uneven ring float will result.

Next examine all over for cracks—the most likely place for this defect to develop is at the junction of the gudgeon pin bosses and sides of the piston; from any of the oil holes, in webs supporting the crown and/or gudgeon pin bosses, from a bruise or other damage on the bottom of the skirt. Remove any deep scores on the skirt but do not bring the piston outside the limits for ovality.

Check the bores of the gudgeon pin bosses for wear and also for alignment, and for being square with the sides of the piston. To do this place the piston, head downwards, on a surface plate, check the sides for being square, allowance being made for the fact that the diameter varies, being larger at the bottom than at the top. Place a mandrel a few thousand smaller than the gudgeon pin through the gudgeon pin bores, check by means of a clock dial indicator. 0·001 in. per inch length is the usual error allowed. Check the outside diameter for size and also for ovality.

Where it is necessary to replace a piston, ensure that the new one is of the same weight as the old one in order that the dynamic and static balance of the engine is not disturbed.

Piston Rings

Clean all over including any holes that may be drilled in scraper rings.

Examine all bearing surfaces for wear. Check the free and working gap. For the former lay the ring on a surface plate, and in the absence of drawing dimensions compare with a new ring.

For measuring the working gap insert a piston (on which a small quantity of thin oil has been smeared) about $\frac{1}{3}$ up the working stroke of the cylinder to which the ring is to be fitted.

Insert the ring in the mouth of the cylinder and gently press up against the piston, thus ensuring that the ring is square, then push the piston clear of the ring, care being taken not to disturb the latter. An accurate measurement of the gap can now be taken with feeler gauges. Refer to makers' handbook as to the range of dimensions that can be allowed for the gaps.

No general figure can be given since they vary considerably, one maker restricting the greatest gap from 0·006 in. to 0·008 in., while another maker will allow 0·015 in. to 0·016 in.

Next check the float of the ring in the groove from which it was removed and to which it will again be fitted.

On most engines the float varies on the different rings, being greatest on the top one, the remainder having a progressively smaller float. Here again actual dimensions vary on different engines, but on most modern engines it is usual to allow about 0·010 in. to 0·012 in. for the top ring and 0·006 in. to 0·008 in. on the lower one. Dimensions for both float and gap also vary in many cases as between gas and scraper rings, and the engine makers' handbook should be consulted on this point.

Gudgeon Pins

These parts are generally made from case-hardened steel and cracks are liable to develop should there be any flexing when the engine is running; therefore, after thoroughly cleaning they should be very carefully examined for this defect. A good light is essential, as in the initial stages this defect is very difficult to detect. Measure for wear and for being parallel.

If pads are fitted for locating the gudgeon pin, ensure that they are a snug fit in the ends and are not unduly worn. Where location is by means of circlips examine the grooves for signs of cracks or other damage. A slot for assisting in the removal of the circlip is also provided in some designs. The corners of such slots must be examined for possible cracks.

Connecting Rods

Beyond an examination of the small ends and ensuring that the big end bearings and wrist pin ends are not unduly slack there is little that the "C" man can do. Of course, if any defect is discovered in the big end or wrist pin ends, the overhaul becomes a complete one, and must be handed over to a ground engineer holding a "D" licence for the particular engine.

If satisfactory, proceed by checking the bores of the small ends for wear and alignment.

Errors of alignment comparable with those referred to above for gudgeon pin bores in the piston can be permitted, and the method of measuring is the same except that the cylinder jointing face of the crankcase is used as a base instead of a surface plate.

Clean and examine all oil holes and/or grooves.

Crankcase

Examine the jointing face for cylinders and clean up where necessary. Beware of cracks which frequently develop from holding down studs. Some makers permit a limited number of these cracks without scrapping the crankcase. Where several cracks are found, ascertain the makers' recommendations in this matter before proceeding further. Examine all studs for damaged threads and for being slack in the case. Where any are found, they must be replaced by studs having oversize threads in the end that screws into the case.

The interior of the crankcase must be examined, particular attention being paid to all split pins, circlips, and/or other locking devices to ensure that all parts are properly retained.

The examination should, where possible, cover all ball or roller bearings to ensure that these are not spinning in their respective housings. Attention must be paid to all supporting webs, especially those for the main bearings. Flush out all oil ways and leads, and where internal oil galleries are fitted examine all joints for possible failure. On those engines where the camshaft is housed inside the crankcase, examine all cam profiles for wear and damage, also the train of gears by which it is driven.

Many engines are now fitted with a small diaphragm type petrol pump which is driven by a cam, sometimes included on the main camshaft. The diaphragms of these pumps have a definitely limited life and must be renewed from time to time in accordance with the maker's instructions. At each overhaul all other working parts must be checked, new diaphragms fitted where necessary or where nearly due for renewal and the reassembled pump checked for efficiency. A diaphragm must be regarded as a vital accessory of the engine, failure of which would most probably have serious results.

Carburettors

Completely strip down and examine all parts. Check the toggle gear and replace any parts that are worn. Examine the float for punctures.

The best way to do this is to immerse the float in boiling water for a

few minutes—if punctured the escape of the expanded air will show up very quickly and the puncture located. Any attempt to repair entails great care. The lightest of soldering irons must be used, and only the smallest quantity of solder used that will suffice to stop the puncture.

Examine the seating of the needle valve and grind in. Where needles and/or seating are of bronze use metal polish as the grinding medium or razor paste where of stainless steel.

Check and adjust the petrol level before assembling on to the engine; this saves a lot of time in the subsequent tuning up.

Magnetos

Ground engineers, excepting those holding the special "X" category licence, are strictly limited in the amount of work they can undertake in the matter of overhauling of magnetos, and must confine their efforts to cleaning, adjusting, and replacing the smaller components.

The contact breaker, distributor, and brushes should, however, be removed, cleaned with a cloth soaked in petrol, and examined for wear. Examine the contacts of the contact breaker and, if dirty or worn, clean up with a piece of very fine emery cloth, being careful to clean away all dust resulting therefrom.

Examine the movement of the bell crank lever carrying the contacts—see that the bearing is free in its bush and lubricate with a smear of light oil. Be sure that no oil is allowed to collect on the contacts or when this oxidizes the efficiency of the magneto will be greatly impaired. On re-assembling the contact breaker on its shaft, make sure of correctly locating it on its key or other means of location.

Examine contact gap and adjust where necessary to 0·012 in.

Most of the present day light aero-engines have one of the magnetos fitted with an impulse starter. Extra precautions are necessary when assembling this to the engine; first in regard to the timing and secondly as regards position.

With reference to timing it is necessary to set the impulse mechanism in its correct relationship to the armature.

Markings are usually provided on the driving and driven members to assist but in case of doubt the magneto makers' instructions on this point must be ascertained before finally locking up. No definite instructions can be given here as the actual settings vary on the different types of magnetos, and also on the different types of impulse starter mechanisms.

On the second point it is important that no end thrust is imposed on the impulse starter mechanism when fitting the magneto to the engine. Unless this precaution is taken there is a danger of the impulse binding and ceasing to function. Even with the comparatively soft serrated rubber compound form of drive so frequently used a definite although small clearance is essential between the two elements of the drive.

Airscrew Shafts

The makers of some geared-engines recommend definite periods of overhaul for the airscrew shaft component—such periods approximating that of top-overhaul of the engine. The following are the main points that must be attended to—

All gears must be closely examined for wear and damage and must also be checked for backlash with the mating gear or gears. On simple reduction gears where the loading is very heavy the makers sometimes lay down very close limits for eccentricity of backlash—i.e. the maximum and minimum backlash recorded on a given number of measurements taken

on one complete revolution of the larger gear must be within, say, 0·003 in. to 0·006 in.

Any serious excess of the actual figures laid down by the makers results in excessive loads on the gears at those points where this excess exists and failure of the gears may result.

Should it be found necessary to replace a gear it should be remembered that many engine makers now match up important gears in pairs or sets, which in turn necessitates their replacement in pairs or sets. Where only one gear requires to be renewed, however, as a measure of economy, the matter may be referred to the makers, who may be able to match up a new gear to the existing good one(s).

All ball or roller bearings must be examined for wear not only for the balls or rollers and/or their tracts, but also to ensure that both inner and outer races have maintained the required fit on the shaft or in their housings, and replaced where found to be slack in their housings.

On most modern engines it is usual to provide spare bearings oversize on outside diameter of the outer race, so there should be little difficulty regarding spares. Where the inner race is slack, metal depositions of the shaft will overcome this trouble.

The airscrew shaft should be checked for truth by mounting on vee blocks on a surface plate and checked by means of a clock dial at the endmost plain portion of the shaft. An indicator figure of about 0·003 in. to 0·004 in. is generally permissible, but should not be exceeded to any great extent or vibration will result.

Examine all key-ways and/or splines for wear and fit with their mating parts. Should any sharp "nicks" or bruises be found, these must be carefully blended out. Remember, abnormal stresses are liable to concentrate at such points and will probably result in a fatigue fracture.

This point should, therefore, receive close attention whenever an airscrew is replaced or refitted.

2. INSTALLING THE ENGINE INTO THE AIR-FRAME

As previously stated the duties of the "A" and the "C" category ground engineer overlap to some extent at this stage, in that the "C" man must ensure that the engine bearers are fit in every way to receive and accommodate the engine. Having visually examined for damage and checked for truth he can offer up the engine but before any attempt is made to bolt down, each and every bearer or foot, in the case of a vee or vertical engine, must be checked by feeler gauge to make quite sure that all are bearing equally on their respective supports.

Should a gap be found at any point where a bolt is fitted, aluminium packing washers of the requisite thickness must be inserted. Unless this precaution is taken, failure of the crankcase may result.

Where rubber bearer blocks are fitted special attention must be paid to these to ensure that the rubber is not perished and has retained its required degree of resilience.

Similar precautions are necessary in the case of a radial engine, excepting that the fit of the spigot is of importance as well as the accuracy of the fit of the case to the bearer plate.

Having satisfied himself on this point the engine may now be bolted down, after which he may proceed with the connecting up of the fuel, oil and water supplies, switch wires, etc. Before doing so, however, he must ascertain by actual test that the supply from these services is adequate for the requirements of the engine.

Starting first with the fuel service, examine the tank and ensure that the interior is perfectly clean and free from corrosion; thoroughly clean out the sump and filter and where of the gravity feed type do not overlook the small hole in the vent. Should there be any doubt on the soundness of any joints the tank should be submitted to a pressure test. To do this fill the tank to about one-third its total capacity with either petrol or paraffin (the latter for preference, but ensure that all traces of this are removed after the tank has been tested). Then paint over all joints with a mixture of whitening and water or methylated spirits, and when this is dry apply air pressure but do not exceed that quoted in leaflet D.3. of A.P. 1208. The tank should now be moved about so that its contents cover all joints in turn.

The pipe lines must next be closely examined throughout their entire length.

Where of copper tube closely examine for cracks, remember that copper tends to crystallize when subjected to vibration over a length of time. Where the pipe is a flexible one, examine for signs of disintegration of the component materials, generally evident by blistering.

Before connecting up to the carburettor(s) check for flow; this should be carried out by means of a calibrated measure (not less than one gallon but preferably two gallons) and a stop watch.

The flow must be 100 per cent *in excess* of the maximum required by the engine. When making this test the tank should contain 10 per cent of its capacity, and the machine should be in the position giving the lowest head on the fuel supply. (See leaflet D.3 of A.P. 1208.)

If this flow is not obtained recheck at the next joint and so on until the obstruction is found. Clear or replace the pipe as may be necessary. In cleaning out a pipe great care must be taken in the selection of the material used for cleaning. Anything in the nature of very soft fabric must be avoided since a certain amount of "fluff" is sure to be deposited in the pipe which will eventually find its way to the filter and in time choke it. A small, stiff, bottle-washing brush is the safest means of effecting this cleaning. If the obstruction cannot be entirely removed the length of pipe affected should be replaced.

Where a dry sump engine is fitted examine oil tank and pipe line. Ensure a full bore flow of oil from the union before connecting up, not only as a check for supply, but also to avoid air locks.

Similar action should be taken with the water service where applicable.

Connect up and check all ignition wiring, both for continuity and for insulation—the former by means of a bell or lamp and battery, and the latter by a megger.

In connecting up the switches remember that they work in the opposite way to the household lighting or power switch, in that when the bridge is closed the magneto is "dead" from the fact that by closing the circuit we divert the current from the primary circuit of the magneto to earth.

The official requirements as to fitting these switches are contained in leaflet D.1 of A.P. 1208.

The induction pipes can now be fitted. Ensure that all joints are air-tight otherwise weak mixtures and consequent overheating of the engine will result. Some engine makers call for a smoke test for this purpose. It is preferable to leave the fitting of the exhaust manifold until after the engine has been tuned up in order that the characteristics of the exhaust flame may be observed.

Before any cowling is fitted all controls must be closely examined joint by joint as well as for correct functioning.

Every joint must be examined to ensure that all pins, etc., work freely, but without undue slack, and are properly lubricated. For the official requirements regarding the correct functioning of controls see design leaflet D.1 of A.P. 1208.

The cowling may now be fitted and finally the airscrew. Before fitting the airscrew examine for defects, including signs of the lamina opening up, also for damage at the tip caused by stones, etc. Where any repairs are necessary it should be re-balanced before fitting.

3. TESTING THE ENGINE AFTER TOP-OVERHAUL

(Normal Aspirated Engines)

It will be noted that the "C" leaflets of A.P. 1208, which deal with the requirements regarding the testing of aero-engines for civil aircraft, do not lay down any tests in the case of top-overhaul. The extent of testing required is left to the discretion of the ground engineer and is dependent on the amount of work done and the relative importance of any parts replaced during the top overhaul.

All tests should, however, be made with a calibrated test airscrew or one of known value.

Where no replacements of importance have been made and the test is, therefore, one to prove assembly only, it may be carried out with the flight airscrew, providing it is the same one that was fitted when the power of the engine was known. This is an important point, since it must be realized and appreciated that no two airscrews, although made from the same drawing, have precisely the same characteristics, due to the necessity for having manufacturing tolerances.

While such tolerances are kept as fine as is practicable from the manufacturing standpoint, it is an established fact that a difference of over 5 per cent in power absorbed is not unreasonable.

Take, as an example, two airscrews for an engine having a normal speed of 2,000 r.p.m. The "revs." on the ground would be of the order of 1,800 to 1,850 with an average airscrew, but owing to the fact that each airscrew happens to be on the opposite extreme of the tolerances, it is possible that one will give 1,780 r.p.m. and the other 1,900 r.p.m.

Supposing the heavy one, giving 1,780 r.p.m., had been fitted originally, but on the test after overhaul the light one was fitted and the engine gave 1,800 to 1,820 r.p.m., the engine would probably be passed as up in power, whereas it is in fact low in power. Conversely, if the light one had been fitted originally and the heavy one fitted for the test in question, the engine giving 1,820 to 1,840 r.p.m., it would most probably be turned down, but in this case it is actually up in power.

The futility of trying to assess power by means of an uncalibrated airscrew is therefore apparent.

Test airscrews are designed to absorb approximately 90 per cent of the rated power of the engine at normal or international r.p.m., and by the cube rule will hold the engine to within about 5 per cent of maximum permissible r.p.m. at full throttle. They thus permit the full range of the tests to be run.

Another point of importance that must be considered is that of cooling, particularly where air-cooled engines are concerned, since we are dependent upon the slip stream from the airscrew to maintain within reasonable limits the temperature of the engine while running on the ground.

Here again there are fundamental differences between test airscrews and those used in flight. In the former the slip stream flows back right over

the engine and effectively cools it, whereas with the flight airscrew, the flow of the slip stream is much wider and little if any is directed over the engine. "Flight" airscrews are therefore quite useless for prolonged running on the ground.

If, in extreme cases, it is quite impossible to obtain a test airscrew, and providing the replacements of major parts have been negligible, it may be permissible to run the engine on the ground with the flight airscrew to ensure that it is giving reasonable power, and to follow this by a short flight, when the power of the engine may be judged to some extent by the performance of the aircraft.

Similar procedure will have to be adopted where the original flight airscrew has become unserviceable for any reason.

We come now to the actual testing. The ground engineer responsible for the overhaul must decide the extent of this, and he must be guided by the amount of work done or number and relative importance of the replacements made.

If, for example, no major parts have been renewed, there is no necessity to strip the engine following the duration test; but if one or more pistons, or equally important components, have been renewed, it becomes essential to strip the engine to ensure that the new part is satisfactory.

In the former case (no major renewals) a run of half an hour at normal or international r.p.m. (assuming a test airscrew is used) terminating with two minutes at full throttle will suffice; whereas in the latter case (where important components have been renewed), the test should be not less than one hour exclusive of any period "running in," again opening up for the last two minutes to full throttle, followed, after an examination of the renewed parts, by a further run of 15 minutes, the last two of which must be at full throttle.

We now come to the actual procedure for running the test. Having examined every part to ensure that everything is properly locked and that the tanks have been filled with the approved fuel and oil, the engine may be started up and run at its lowest speed, which should be at about 400 r.p.m. Observe the oil pressure closely. This should drop very gradually as the oil becomes warm, but should it drop suddenly or should there be no pressure recorded in the gauge, stop the engine and investigate the cause.

Assuming, however, that the pressure is satisfactory, gradually open up to about half throttle and, with the engine running, go round to see that all external parts are working satisfactorily and that the distribution of the gas is reasonably even. Open out the throttle for a short burst and see that the engine will give its "revs."; but before proceeding with the test proper, shut down and go all round the engine and installation to make quite certain that all parts are quite tight.

Restart the engine and proceed with the tuning up. Open the throttle until the engine is running at or near normal r.p.m. See that it is running quite steadily, and that there is an entire absence of vibration. If this defect is present, trace the cause. This may be due to one or more of the following causes: the bearer bolts or adjacent parts being slack; the airscrew not being properly secured; incorrect mixture strength, or unequal distribution of the fuel; incorrect timing of either the valves or of the magnetos; local air leaks, etc.

Of these defects probably the most harmful is that of a weak mixture which, in addition to setting up vibration, causes overheating also. It is most readily detected (providing the test is being run at night, or in a subdued light), by examination of the exhaust flames. (It is here assumed that the exhaust manifold has not been fitted as was suggested earlier.)

The flame should be of a steady Bunsen blue. A weak mixture is usually denoted by the flames being short and of a green-blue colour, and a rich mixture by red flames smoky at the tip.

These colours do not, however, appear in the order given on all engines, and are only quoted here as a general guide. Experience on a particular engine is necessary before an exact determination of mixture strength can be arrived at by this means.

Uneven distribution should not arise if the engine has been correctly assembled, and if present will most probably be found to be due to an air leak at the joint between the cylinder showing the weakest mixture and the induction pipe or manifold. It may also be caused by excessive clearance of a valve in its guide or from a defective valve seating. Incorrect carburettor setting is another possible cause.

Finally, the airscrew may be the cause of the trouble. Having again made quite sure that it is properly secured to the airscrew shaft, check for accuracy of track of the various blades. To do this, from a point on the leading edge of one of the blades about one-third up from the tip, measure the distance to some convenient fixed and rigid point on the machine or test bed. Turn the airscrew until the next blade occupies the same position as the first one and again measure the distance from a similar point on the blade to the same point on the machine or test bed, and so on, until each blade has been so measured.

The difference in the measurements obtained gives us the amount the airscrew is "out of track." For an airscrew 6 ft. to 8 ft. diameter, this measurement may safely be $\frac{1}{4}$ in. to $\frac{3}{8}$ in. without causing vibration.

Having satisfactorily tuned up the engine, the correct independent functioning of each magneto must be checked by switching off first one and then the other and noting the drop in r.p.m. on each magneto.

The drop should not be more than $2\frac{1}{2}$ per cent, and must not exceed 5 per cent on most types of engines. This test should be repeated several times during the test of the engine.

4. SUPERCHARGED ENGINES

These engines are not at present in general use in civil aviation except by the larger operating companies, but this book would not be complete without some reference being made to them.

As far as top overhauls are concerned the work involved is largely the same as that on normally aspirated engines, except that we have to deal with the addition of the supercharge unit.

The ground engineer desirous of having this class of engine included on his licence or any engine to which a supercharger is fitted, is required to have a reasonable knowledge of the theory of supercharging; some experience of the special precautions necessary during testing and, in fact, during any running at sea level; and a detailed knowledge of the construction of the unit embodied on the engine or engines he wishes to have included on his licence. The following notes are therefore included as a guide to the new candidate and to those wishing to have engines of this type added to their licence.

Since the volumetric efficiency of all I.C. engines is largely dependent on the weight of the charge entering the cylinders, it follows that there must be a loss of efficiency of the engine as the aircraft ascends and the density of the air becomes less.

Supercharging was therefore originally applied to aero-engines for the purpose of overcoming this loss, and such engines had their power rated at a defined height above sea-level.

There have recently, however, been introduced supercharged aero-engines rated at ground level; supercharging in this instance being introduced for the purpose of giving additional power for take off and climb.

In both types supercharging is effected by the introduction of some form of compressor—generally a blower or fan—in the induction system, whereby the pressure in the latter is increased.

This blower is driven through gearing by the crankshaft, some form of clutch being embodied in the drive to absorb undue shocks resulting from acceleration and deceleration, the actual ratio of speed between crankshaft and blower being arranged according to the degree of supercharging required. This varies on different engines from slightly forced induction to what is known as "fully supercharged."

This increase of pressure in the induction system is known as "boosting," or boost pressure, and since it imposes increased stresses on practically every part of the engine it is vitally necessary that this pressure be confined, within certain limits, to that laid down by the engine designer.

The pressure in the induction system must therefore be constantly measured in the same way as that of the oil in the lubricating system of the engine. Due to the comparatively small but important variations of pressures (*absolute pressure as distinct from gauge pressure*) that have to be measured, the ordinary pressure gauge cannot be used for this purpose.

A special form of gauge known as a "boost" gauge is used instead. This, as explained further on in this section, is constructed on similar principles to that of an aneroid barometer, a type of instrument that is very sensitive to small variations in pressure, and compensates for variations in the atmospheric pressure.

The installation of these engines in an aircraft presents few difficulties not met with in the installation of a normally aspirated engine.

The real difference lies in testing after overhaul.

This we must consider under the two classes, viz. (1) those rated at an altitude, and (2) those rated at ground level.

The former class presents the greater difficulties, as special apparatus is required to test the engine for power after overhaul.

This apparatus includes a depression box fitted with adjustable orifices by means of which the air supplied to the carburettor may be maintained at a reduced pressure corresponding to the barometric pressure at a given altitude. Difference of pressure within the box and that of the air outside is measured by means of a mercury U-tube, and the figure at which this reduced pressure must be maintained is obtained by subtracting the barometric pressure at the altitude at which the engine is rated from the barometric pressure on the ground at the time and place the test is being run.

A thermometer must be fitted to the depression box in order that the temperature of the air within the box may be recorded, this being an important factor in the corrections that have to be made in the final calculations for performance.

The test is run on a calibrated airscrew and during the test observation must be recorded of the R.P.M., depression pressure, boost pressure and air temperature.

The normal power developed by the engine is obtained from the calibration curve of the airscrew. This must now be corrected for the various factors affecting engine performance.

These factors vary somewhat on different engines, and the reader is referred to the engine-maker's handbooks, which invariably include tables

of constants, and/or graphs, from which a finally corrected figure for performance is readily obtained.

Precautions have of necessity to be taken on all installations to prevent the possibilities of the engine being over "boosted," and the greatest danger of this occurring is at the moment of "take off" when the pilot's attention is fully occupied with other matters. A "gate" is therefore introduced in the engine controls which must not usually be passed through until the aircraft has reached a predetermined height above the ground.

The actual setting of this "gate" forms an important part of the duties of the ground engineer, since it must be so arranged that there is an ample margin of power for "take off" while at the same time the boost pressure must not exceed that laid down by the engine designer and approved for "take off" purposes.

This approved pressure varies on different engines and may be either rated boost pressure, or maximum permissible boost.

In setting the "gate" this point must be very carefully noted, and if in any doubt reference must be made to the engine log book.

Another point that must not be overlooked at this stage is the fact that the zero marking of the boost gauge represents normal atmospheric pressure at sea level at 15° C., i.e. 760 mm. of mercury or 14·7 lb.per sq. in., and a true zero reading will only be obtained when these conditions exist. The normal reading obtained will therefore be either plus or minus, according to the atmospheric conditions prevailing at the time.

Consequently, before the "gate" can be finally set reference must be made to a reliable barometer, in order that due allowance may be made for this variation of atmospheric pressure on the boost gauge.

Many of these engines are fitted with a device which automatically controls the boost pressure, thereby obviating the necessity for fitting the "gate." This generally consists of a servo motor controlled by an aneroid. The latter is contained within a casing which is connected to the induction system by a pipe. Any variation of pressure in this system causes the aneroid to expand or contract as the case may be. A rod is attached to one end of the aneroid which operates a valve which controls a supply of oil under pressure from the main lubricating system, to either the top or bottom of the piston of the servo motor. The piston, in turn, is connected mechanically to the throttle controls, and the pressure in the induction system is thereby maintained within predetermined limits.

An overriding device is embodied by means of which additional boost may be applied by the pilot for take-off purposes. A fuel enriching device is also fitted in some cases for the purpose of suppressing detonation at the higher boost.

These controls require to be very carefully maintained, as they are vital to the correct functioning of the engine. Owing to the many small but important variations in the actual adjustments necessary on the different types of engines, the reader is referred to the handbooks of the individual engines for details, and to treat the above notes as general only.

Coming now to the other class of supercharged engines, i.e. ground boosted types, the principal difference, from the ground engineer's point of view, is that they can be run on the ground at full boost, and that they obviate the necessity for fitting a "gate."

They must, however, be treated with the same care during installation and testing to ensure that they develop the necessary power without exceeding the boost pressure approved.

Further particulars on the adjustment of boost gauges, with tables

showing allowances to be made for variations in atmospheric pressure, will be found in Section 2, Chapter VI, of A.P. 1274.

5. THE ESSENTIAL INSTRUMENTS USED IN THE ENGINE INSTALLATION

Engine Speed Indicators

These instruments usually work on the governor principle, and consist of a central shaft, which is driven, either direct or through a gear box, at $\frac{1}{2}$ engine crankshaft speed. Weights which are pivoted on this shaft tend to fly outwards by centrifugal force as the shaft revolves.

The movement of the weight moves a collar which slides on the central shaft and this movement is transmitted by means of a pinion and quadrant to the pointer moving over the dial. A spring is fitted which returns the weight to its normal position as the speed of the engine is reduced.

The instrument is connected to the engine or gear box by means of a flexible shaft. The latter is supported in a flexible casing, lubrication between the two being provided by an approved grease retained by asbestos packed casing.

The inner or driving shaft is fitted at either end with a solid connection of square sections which fit into a corresponding square hole in the engine, or gear box at one end, and in the instrument at the other.

When installing these instruments care must be taken not to make too many bends in the drive, and that no bend is less than 9 in. radius.

The average ground engineer generally has very limited facilities for testing this class of instrument, and can only make a comparison with another instrument of known accuracy. This should be done by means of a two-way gear box, driven by an electric motor the speed of which can be varied over a fairly wide range.

Alternatively the drive can be taken from the engine. The instrument of known accuracy should be connected to one of the dual drives and the one to be tested to the other. A direct comparison of readings over the range of the instrument can be made.

Pressure Gauges (other than Boost Gauges)

These all work on the Bourdon principle and consist of a bronze tube of oval section which is bent to form an arc. The tube is sealed at one end and open at the other.

The open end is attached to a union which is fixed to the case of the instrument, while the closed end is free to move but is connected by light link motion and quadrant to the spindle on which the pointer is mounted.

On pressure being applied to the open end, the tube tends to straighten, and in doing so causes the pointer to revolve over the face of the dial in proportion to the pressure applied.

The principal precautions to be taken on installing these instruments are, first to ensure that the service—oil,water, etc.—to be tested is actually reaching the instrument, and that there is no air lock or other obstruction in the pipe line of the particular service. For example, take the lubricating oil service.

Before making the actual connection between the service pipe and the pressure gauge, the engine should be turned a few times or until the oil begins to flow from the end of the pipe. It is also necessary to make quite

sure that a tight joint is made not only for cleanliness, but also to ensure that there may be no loss of pressure, and that the amount shown on the gauge truly represents the service concerned.

Testing is again, as a general rule, limited to a comparison with a similar instrument of known accuracy.

Make up a gallery of copper tube with three connections—two for the two instruments and the third for connecting up a pump. A comparison at two or three points over the range of the instrument should suffice to prove accuracy.

Temperature Gauges

These work on the same principle as the pressure gauges, and are of very similar construction except that the open or fixed end of the Bourdon tube is permanently fixed to a capillary tube of steel, copper, or copper-nickel, having a very small bore. At the other end of the capillary a length of brass tube or "bottle" is fitted. The latter is partially filled with ethyl ether or similarly volatile liquid, the remainder of the "bottle," the capillary tube and the Bourdon tube are filled with vapour from the liquid. On subjecting the "bottle" to any increase in temperature the vapour pressure increases through the whole system, and the Bourdon tube tends, in consequence, to straighten out in the same way as in the case of the pressure gauge. The dial readings of these instruments are therefore changes in pressures although calibrated in degrees of temperature.

Temperature gauges are also made in which the medium used for transmitting change in temperature is mercury instead of vapour pressure. This type of instrument is more accurate than those referred to previously.

In construction the principal difference lies in the Bourdon tubes, which instead of being a simple arc consist of several coils.

A simple check for accuracy can be made by immersing the "bottle" of the instrument in a vessel of water and gradually raising the temperature of the latter and comparing the readings of the instruments against those of an ordinary glass thermometer of known accuracy, placed as close as possible to the "bottle" in the water.

The water must be constantly stirred in order that its temperature may be equal throughout or serious errors in calibration may result from local hot spots in the water.

These instruments, especially where of the vapour pressure type, need to be handled with great care when installing to avoid damage, particularly to the joints of the capillary. This will result in an escape of the transmitting medium, which will be readily detected by smell. Damage to the mercury type will be evidenced by the escaping mercury which is under fairly high pressure within the instrument.

No attempt should be made to repair these instruments. Without the proper facilities and elaborate apparatus necessary for carrying out such work with any degree of success it is most probable that the attempt will result in irreparable damage being done to the instrument. It is more economical, therefore, in case of damage, to forward the instrument to some works having the proper facilities.

Boost Gauges

These work on the same principle as an aneroid barometer or altimeter in that they consist of a shallow corrugated metal box from which the air has been exhausted. Any reduction of pressure of the air on the outside of the box permits the latter to expand. This diaphragm movement is

transmitted through suitable mechanism to the pointer working over the face of the instrument which thus registers variations in pressure.

Their purpose is to measure the difference between the pressure of the air outside and that of the charge of gas within the induction chamber.

Actually the zero marking on the dial represents normal atmospheric pressure at sea level, i.e. 760 mm. of mercury or 14·7 lb. per square inch.

Figures on the right or in a clockwise direction represent increase of pressure while those to the left or anti-clockwise a decrease.

It must be fully appreciated that a true zero reading will only be obtained when the barometer stands at 760 mm. at the time and place the reading is taken, and that any variation in the barometer or in altitude will be reflected on the gauge reading being above or below zero, although the instrument is not connected in any way to the engine.

These instruments are generally marked to show the maximum variation in pressure for the particular engine to which they are fitted. When changing an instrument it is therefore important to note that this marking is correct for the engine to which it is now being fitted. Failure to observe this point and to fit an instrument incorrectly marked may result in the pilot over boosting the engine and possibly wrecking it.

Leaflet E.1 of A.P. 1208 details the requirements in connection with the installation. Reference should also be made to "Aircraft Instruments," by R. W. Sloley, published in this series; and to "General Instrument Equipment for Aircraft," Air Publication No. 1275, obtainable from His Majesty's Stationery Office.

6. GENERAL NOTES AND HINTS

The keynote of the ground engineer must be "system," for unless all his duties are carried out systematically, he is bound sooner or later to overlook some minor point that may result in a major defect arising. All duties should therefore be carried out to schedule, and these should be prepared for all phases of a ground engineer's duties.

As far as the overhaul of the engine is concerned, many of the makers include in their handbooks schedules for 10 hours, 25 hours, 50 hours, etc., examinations. These will form a good basis, to which must be added the many points peculiar to a particular machine or installation and the list of modifications referred to previously.

Apart from the value of these schedules to the ground engineer, the fact that his work is carried out systematically inspires confidence in the users of the aircraft. Incidentally, the more important operating concerns have printed schedules, a copy being used for each overhaul, and every item has to be signed for by the ground engineer who passed the particular item of work.

In addition to the schedules a rough notebook should be maintained in which particulars of all work done on an engine or adjustments made to the installation should be entered. These notes are not only necessary for the subsequent completion of log book entries, but since there is not the same need for brevity they can be elaborated and include minor observations of value for reference at a subsequent examination. A periodic review of such notes will often suggest additional items for inclusion in the schedules.

It is false economy to attempt to fit circlips, split pins, and similar locking devices that have been used previously. These parts become unduly

stressed in the process of assembly and dismantling, and their safety factor if reassembled is reduced considerably.

Therefore, make a practice of destroying these parts as they are dismantled in order to prevent their future use.

It is often found that a costly part has become worn at one or two points only—say on a journal which carries a ball or roller bearing. Such parts if otherwise serviceable can be salved by electrically depositing metal on to the worn surface to bring it up to its original or even to slightly larger dimensions. Only iron or nickel should be used for this purpose, copper being too soft. This work may only be entrusted to firms whose process has been approved by the Air Ministry.

The process can be applied to almost any part where the skin friction loading is not too high. It should not, however, be used for making good wear on splines of highly stressed shafts and similar parts, since there is a danger from the deposit obscuring some defect developing in the base metal.

When entering particulars in the engine log book of any replacements made it is a good plan to quote the Release Note No. under which the part(s) fitted were received.

This is outside the official requirements, but the record may be of value at some future date should any trouble arise with the part(s) in question. It also tends to condense records.

PART II

THE LAW RELATING TO CIVIL AVIATION

By A. McISAAC

INTRODUCTORY—National Control of Flying—International Control of Flying—Control of Flying in Great Britain—Conditions of Flying—Compulsory Instruments and Equipment—Personnel and Log Books to be Carried—Rules for Air Traffic—Lights and Signals—Customs—Pilots' Licences—Navigators' Licences—Ground Engineers' Licences—Conclusion

Introductory

CIVIL aviation as a factor in the practical everyday life of any community can be said to have been non-existent prior to the Great War, 1914–1918. Any flying which took place before then—the first flight made by Wright, the crossing of the Channel by Blériot, and other flights in the various competitions and demonstrations that were held—can be looked upon as being of the nature of experimental or sports flying.

Immediately following the Great War there was a rapid and intensive development of the use of civil aircraft for the purpose of the public carriage of passengers and goods. From this point of view it may be admissible to look upon the year 1919 as that in which civil aviation as a practical means of transport actually had its birth.

It will be evident that this rapid development very soon rendered urgent the question of control of aviation. Such control can be exercised most effectively by the authorities responsible for the public business of any given community and in this country control is effected by means of Orders and Directions which are based on an Act of Parliament known as the Air Navigation Act.

In the following pages is given an outline of the main points in the law relating to civil aviation that will help the reader to a clearer understanding of those things with which he ought already to be acquainted. No attempt will be made to cover the whole field and it cannot be hoped that the study of the information given here could ever be accepted as a substitute for a study of the various Orders and Directions themselves. A full understanding of the matters involved can only be gained by the detailed study of the official pronouncements. It is useful to think of the very large body of motorists who serenely carry on without any accurate knowledge of the law relating to road traffic. The average motorist's knowledge of that law is confined to those little bits of information he acquires from reading press accounts of prosecutions under the Road Traffic Act, or, in some cases, by means of the more unpleasant way when he himself has been prosecuted and perhaps penalized. Despite the possible serious consequences arising from his ignorance, the motorist does not seem to think it worth while to make a personal study of the Road Traffic Act.

It may be that aviators as a body differ in this respect and do in fact know the provisions of the various air regulations, but in case this should not be so, the attempt is being made here to outline the main requirements that are peculiar to aviation. It should be borne in mind, however, that

aviators, like everyone else, are subject to numerous laws, the understanding of all of which would make one the complete lawyer. No attempt, therefore, will be made to deal with common law, insurance law, customs law, or any other of the various special laws that may be involved in aviation. Ignorance of the law cannot be pleaded as a defence in any proceedings, and it is the purpose of the following pages as far as possible to reduce ignorance of the law relating particularly to civil aviation.

National Control of Flying

Control of civil aviation in Great Britain and Northern Ireland has been effected through various Acts of Parliament, several of which were placed on the Statute Book between the years 1911 and 1919. As a result of the large development of civil aviation and other causes following the Great War, a new Act was passed including all the previous provisions, which Act is known as the Air Navigation Act, 1920.

Under the provisions of this Act, Statutory Rules and Orders are issued from time to time by His Majesty's Privy Council. The first of such Orders was the Air Navigation Order, 1922. This was superseded and cancelled by the Air Navigation (Consolidation) Order, 1923. Both the Air Navigation Act of 1920 and the Air Navigation (Consolidation) Order, 1923, are still in force.

Detailed administration of the Act is effected by means of the Air Navigation Directions, which are issued from time to time by the Secretary of State for Air.

Control is similarly effected in British Colonies and Protectorates by means of the Air Navigation (Colonies, Protectorates, and Mandated Territories) Order which differs from the Air Navigation (Consolidation) Order only in such respects as are required for the various local conditions. In turn, the Governments of the various Colonies issue Air Navigation Directions covering the detailed requirements of the Order.

Unlike the Colonies, the Dominions, with their own legislatures, have their own Acts, Orders, and Directions, which are independent of their British counterparts and only related thereto indirectly.

This consideration of national control leads naturally to the question of international control, which is dealt with in the following paragraphs.

International Control of Flying

International control of such things as shipping and communication (postal, telegraphic, wireless) is effected by means of various Conventions which have been the subject of discussion, negotiation, and agreement between the countries concerned. In the same way, aviation is controlled internationally by a Convention ratified by many countries. This Air Convention, dated in Paris the 13th October, 1919, was formulated and signed by plenipotentiaries of the signatory States. It came into force on the 11th July, 1922. The Convention has been ratified by most of the principal nations of the world, notable exceptions being Germany, Russia, Spain, and the United States of America.

The administration of this Convention is vested in a permanent Commission known as the Commission Internationale de Navigation Aérienne (C.I.N.A.) or, in this country, as the International Commission for Air Navigation (I.C.A.N.). This Commission, composed of representatives appointed by the contracting States, is placed under the direction of the

League of Nations and is charged with the duties of modifying or amending the provisions of the Convention or its technical Annexes, the dissemination to the contracting States of information of every kind concerning international air navigation, and so on. Modification of the Convention or of its various technical Annexes is effected by means of Protocols, which likewise are subject to the ratification of the various countries subscribing to the Convention.

The subjects dealt with by this Convention are numerous and important. They include airworthiness, certification and registration, marking, personnel, equipment, customs, navigation, lights and signals, meteorology, traffic rules, and other matters connected with aviation which may have an international bearing.

Flying between any two States which are parties to the Convention is more or less straightforward and is governed by the requirements of the Convention itself. On the other hand, flying to or from a country which is not a contracting State may lead to difficulties and the aviator should make himself conversant with any other agreements or rules that may be in existence. Many agreements of such a bilateral nature exist; for example, that between Italy and Spain, and that between the United States of America and Canada.

It will be evident to the reader that international regulation is necessary if international flying is to be undertaken, but it may not be so evident that international requirements must reflect to a large extent the main points in the regulations of the various States. Quite naturally the international reacts back on the national, so that the tendency is towards a standardization of these requirements.

The Convention therefore sets out rules that are more or less in line with those existing in this country. Thus it is seen that aircraft must be registered and in possession of a valid certificate of airworthiness, the personnel (pilots, navigators, and engineers) must be licensed, prescribed log books must be carried, equipment as laid down must be fitted, and the aircraft must be operated in conformity with specific traffic rules and rules as to lights and signals.

The minimum requirements relating to the strength of aircraft have not yet been agreed upon internationally, and until such has been done these minimum requirements are determined by each of the contracting States according to its own ideas in the matter.

The qualifications required by licensed personnel is a matter on which agreement has been reached. We thus find in the Convention that pilots of private flying machines have to produce evidence of competency by undergoing practical flying tests whilst pilots of public transport machines have to undergo much more severe practical flying tests (including night flying) and to pass a technical examination on machines, engines, traffic rules, and elementary meteorology.

In the fields of meteorology, ground markings and lights and signals, we meet with those points on which international agreement is a *sine qua non*. Meteorology, for example, either from the point of view of its development as a science or that of its practical utilization for flying, is dependent on international co-operation. It is in these branches of the art of flying that the Convention lays down rules codified to the greatest extent.

A detailed examination of some of the requirements operating in Great Britain will be made later, and, as these to a very large extent are similar to the international requirements, no more need be said here regarding the Convention.

Control of Flying in Great Britain

The aviator in Great Britain is essentially bound by the Air Navigation Act, 1930, the Air Navigation (Consolidation) Order, 1923,[1] and the Air Navigation Directions,[2] all as amended to date. The Air Navigation (Consolidation) Order will repay careful study from the point of view of the general conditions of flying and the Air Navigation Directions from the point of view of the technical requirements relating to machines and personnel.

In addition to these Orders and Directions, the Air Ministry frequently publishes Notices to Airmen which are of an explanatory or warning character.

It cannot be too strongly urged that all aviators should acquire a knowledge of the Orders and Directions. Without this knowledge infringements may be committed which may lead to serious penalties or consequences. It will suffice here to point out that any infringement of the regulations could lead to the imposition of a fine of £200 or to six months' imprisonment, or both. In addition to these penalties, circumstances may arise where licences may be suspended or cancelled, and, further, an aircraft may even be fired on if it is flown over a prohibited area.

Conditions of Flying

Perhaps the main requirements that must be met before a machine may fly are that—

A.N. Order, Art. 3

(*a*) The machine must have a Certificate of Airworthiness and a Certificate of Registration; the pilot must be licensed; or

(*b*) In the absence of the aforementioned certificates, the machine must have a permit to fly, in writing, from the Secretary of State for Air; or

A.N.D. 11, Para. 60

(*c*) The machine must be flown under special conditions outlined in the Air Navigation Directions known as the "A" or "B" conditions.

The first two cases mentioned above are self-explanatory. The case at (*c*), however, requires some explanation. Formerly it was permissible for unlicensed or unregistered aircraft to be flown provided that the flight took place within three miles radius of a recognised aerodrome. This very elastic condition was open to serious abuse and is no longer in force. The "A" or "B" conditions are designed to allow the same or even greater latitude under proper safeguards. Briefly stated, the "A" conditions permit the flying of an aircraft without a certificate of airworthiness provided that the flight is a *bona fide* test flight under authorised supervision for the purpose of the issue or renewal of a certificate of airworthiness; the "B" conditions relate to experimental flying in such a way that certain people, including most of the established aeroplane constructors, are authorised to fly anywhere in the country machines which are neither registered nor certified as airworthy, the only requirement being that the machines, if not already registered and bearing the normal registration marks, bear a distinguishing mark which is allotted to each such authorised person to show that the machines are being flown under these conditions.

A.N. Order, Schedule I

The Certificate of Registration for any aircraft (fee, £1 1s.) lasts indefinitely and depends only on the continuation of ownership of the machine by one individual.

[1] The Air Navigation (Consolidation) Order, 1923, published by H.M.S.O. at 1s. 3d.
[2] The Air Navigation Directions, 1932 (A.N.D. 11), published by H.M.S.O. at 9d.

The Certificate of Airworthiness lasts for one year and is renewable, the fee for initial issue (in the case of "subsequent" aircraft) and for renewal being £5 5s. on each occasion.

A.N. Order, Schedule II

The issue of a certificate of airworthiness for a new type of aircraft depends on official approval of design, official inspection of construction and official flying trials.

It is to be noted here that the modification of an existing aircraft likewise requires official approval of design and official inspection, but official flying trials are not always required in such cases. The fees payable for a "type" certificate of airworthiness vary with the tare weight of the machine and are specified in the Air Navigation Order.

A.N.D. 11, Para. 36

The issue of a certificate of airworthiness for a subsequent aircraft (i.e. a replica of a type already approved) follows a recommendation made by approved constructors or, where the constructor is not approved for the purpose of such recommendations, by the Aeronautical Inspection Directorate, Air Ministry.

A.N. Order, Schedule II, Para. 2

Aircraft are always certified as airworthy (i.e. a certificate of airworthiness is issued) in one or more of three categories: "Normal," "Acrobatic," "Special"; and in one or more of a number of subdivisions as: "Subdivision (*a*), Public Transport for Passengers," "Subdivision (*d*), Private," "Subdivision (*f*), Racing or Record." It is the responsibility of the pilot to see that the machine is not used for any purpose for which it is not certified.

A.N.D. 11, Paras. 37 & 38

Renewal of the certificate of airworthiness is dependent on the inspection and recommendation of an authorised inspector. "Hire and Reward" machines (i.e. machines engaged regularly in what is best described for this purpose as fare-paying passenger carrying) are inspected and recommended for renewal by the Aeronautical Inspection Directorate. All other machines are inspected and recommended for renewal by the Joint Aviation Advisory Committee, which is an organisation composed of two older bodies, Lloyd's Register and the British Corporation Register of Shipping and Aircraft. The Joint Aviation Advisory Committee has been specially approved by the Air Ministry for such activities. It will be noted from the foregoing that a subsequent machine may be built, certified as airworthy and its certificate of airworthiness renewed without any official intervention.

A.N. Order, Schedule II, Para. 3

There are other general conditions of flying, amongst which may be mentioned the following—

A.N. Order, Art. 4

A flying machine may not land in nor fly over any prohibited area at a lower altitude than 6,000 ft. The prohibited areas are defined in the Order.

A.N. Order, Art. 15

Every flying machine must carry the prescribed documents. In all cases these include the certificates of airworthiness and registration and a journey log book kept up to date.

A.N. Order, Art. 13

Dropping of articles from aircraft in flight is strictly prohibited except in the case of ballast allowed by the Order, i.e. fine sand or water, or as permitted in writing by the Secretary of State.

A.N. Order Art. 9

An aircraft may not be flown over any city or town except at such an altitude as will enable it to land outside the city or town without means of propulsion. An aircraft must not be used to carry out any trick flying or exhibition flying over any populous area or over any concourse of people, such as a regatta or a race meeting, without the written permission of the promoters, nor may it be flown at such a low altitude as to cause unnecessary danger to persons or property.

A.N. (Amendment) Order, 1933

An aircraft may not be used for wing-walking or any other such exhibition purpose for which the structure has not been designed, unless permission in writing for such purpose has been obtained from the Secretary of State.

A.N. Order, Art. 14

Every aircraft must carry the prescribed instruments which must be maintained in working order.

A.N. Order, Art. 18

An aircraft engaged on international flying must not be used for the carriage of explosives, arms, or munitions of war.

A.N. Order, Art. 22 and Schedule VIII

Every aircraft flying to or from this country must land at or take off from a Customs aerodrome and must pass between such points as may be prescribed.

The foregoing conditions are applicable in all cases, but in addition to these there are certain further conditions applicable to hire and reward machines. These include the following—

A.N. Order, Schedule II

Any aircraft plying for hire and reward is not permitted to fly unless it has within twenty-four hours been inspected and certified as safe for flying. This inspection and certification must be made by licensed ground engineers. The certificate, which lasts for twenty-four hours, is made out in duplicate, one copy being carried in the journey log book and one copy retained by the owner for six months.

The pilot of any such hire and reward machine must satisfy himself that the aircraft is satisfactorily loaded for safety in flight.

For the purpose of so satisfying the pilot in the case of any flying machine which may be employed on a regular line or service of public air transport, a load sheet containing the prescribed particulars must be completed and submitted to the person in charge of the aircraft. This load sheet must be kept by the owner of the aircraft for six months.

Compulsory Instruments and Equipment

A.N. Order, Schedule II, Para. 9

The pilot of an aircraft is responsible for seeing that it is furnished with the prescribed instruments and equipment. What these must be depends on the classification of the machine and the purpose of the given flight. The main points to be remembered in this connection are set out in tabular form opposite. It will be seen that certain equipment is essential in all machines during all flights and that the additional compulsory equipment can readily be ascertained for flights in the special circumstances enumerated.

Personnel to be Carried

In addition to any other specified members of the crew, every flying machine used for the international carriage of passengers or goods for hire

or reward must carry a navigator with first or second class licence if flying—

A.N.D. 11, Para. 78 more than 100 miles over inhabited regions or more than 100 but not more than 625 miles over the high seas or uninhabited regions or, by night, more than 16 miles but not more than 625 miles.

In the same circumstances a navigator with a first class licence must be carried if the machine is flying—

A.N.D. 11, Para. 79 more than 625 miles over the high seas or uninhabited regions or, by night, more than 625 miles.

In certain circumstances the pilot who holds the necessary navigator's licence may, even if he is alone on board, fulfil the duties of navigator in the former case.

	Classification of Aircraft	Nature of Flight	Compulsory Instruments and Equipment
A.N.D. 11, Para. 23	All flying machines	All flights	Air speed indicator Altimeter Revolution indicator, and Such gauges as are considered essential (usually approved as a part of the type design of the aircraft) Safety belt for each person in an open cockpit and for the pilot(s) whether in open cockpits or not
A.N.D. 11, Para. 63	All flying machines	Flight by night	Navigation lights Illumination for instruments and equipment
	Amphibian flying machines	All flights	Indicator of position of landing wheels
	Hire and reward flying machines	All flights	Fire extinguisher (if 10 or more seats are fitted, one for each main compartment, with a minimum of two extinguishers) Wireless apparatus (if 10 or more seats are fitted)
	Hire and reward flying machines	Flights extending beyond 20 miles from point of departure	Compass Watch Turn indicator (if more than 5 seats are fitted)
	Hire and reward flying machines	Flights at any point of which the machine is more than 10 miles from land	Lifebelt for each person on board
	Hire and reward flying machines	Flight by night	Landing lights (lamps or wing-tip flares)

Log Books

Every aircraft must carry a journey log book. In addition every aircraft engaged in hire and reward flying must be provided with an aircraft

A.N.D. 11, Sect. X

log book and an engine log book for each engine. Where aircraft and engine log books are not compulsory, a suitable book is to be kept in which repairs, replacements, and like matters may be recorded.

Rules for Air Traffic

A.N. Order, Schedule IV, Para. 21

Flying machines (i.e. power-driven heavier-than-air craft) must always give way to airships and to balloons whether fixed or free.

The rules regarding risk of collision between power-driven aircraft may be summarised as follows—

A.N. Order, Schedule IV, Paras. 26 *et seq.*

When two aircraft are meeting end on, or nearly end on, each must alter its course to the right.

When two aircraft are on courses which cross, the aircraft which has the other on its own right side must keep out of the way of the other.

An aircraft overtaking another must keep out of the way by altering its own course to the right and must not pass by diving.

Every aircraft following an air traffic route, which has been officially recognised, must keep such route at least 300 yards on its left.

These may be said to be the main points to be observed whilst in flight and away from the aerodrome. There are many other points involved whilst the machine is at, leaving, or approaching the aerodrome. As these do not lend themselves to simplified description and as any failure in their observance might involve litigation or other heavy expenses in connection with third party damages or insurance, the interested reader is advised to refer directly to the appropriate section in the Air Navigation Order.

Lights and Signals

Navigation lights are compulsory for all aircraft flying by night. The lights to be shown are as follows—

A.N. Order, Schedule IV, Sect. 1 (A)

On the right side: a green light,
On the left side: a red light,
At the rear: a white light,

all of which lights are to be visible over a prescribed distance and in prescribed angles.

If the maximum span of a flying machine is less than 65 ft., one lamp placed centrally and combining these three requirements may be used.

In addition to the lights mentioned above, every flying machine which is under way on the surface of the water, under control and not being towed, is required to display a white light to show forward and be visible at a prescribed distance and in a prescribed angle.

An aircraft wishing to land at night on an aerodrome having ground control must make intermittent signals either with a lamp or projector other than the navigation lights, or with any sound apparatus. In addition it must signal in Morse code by the same means the two-letter group composed of the first and last letters of its five-letter registration mark. Permission to land will be given by the same two-letter sign from the ground in green light, followed by intermittent signals of the same colour.

A.N. Order, Schedule IV, Sect. II

The firing of a red light or the display of a red flare from the ground is to be taken as an instruction that the aircraft is not to land.

An aircraft compelled to land at night must, before landing, make with its navigation lights a series of short and intermittent flashes.

Customs

A.N. Order, Schedules VIII and IX

Any aircraft going abroad or coming from abroad must leave or land at a Customs aerodrome, and, in addition, must cross the frontiers between specified points. Where circumstances beyond the control of the pilot force it to cross frontiers elsewhere, the machine must be landed at the nearest Customs aerodrome, and if it is forced to land before reaching such an aerodrome, the pilot is required to report the matter immediately to the nearest police or Customs authorities. In either case the machine may leave again only with the permission of these authorities.

In every case of export, the consignors are required to make a detailed Declaration of the goods in question, and, in addition, a Manifest or general declaration of cargo is to be provided for each such journey of every aircraft. Both these forms are prescribed by the Commissioners of Customs and Excise.

Clearance by the Customs authorities is required before the aircraft may leave a Customs aerodrome and for this purpose the pilot has to produce to the Customs officer—

(*a*) The Journey Log Book,

(*b*) The Manifest and Declaration mentioned above, and

(*c*) An application for clearance on a prescribed form in which is to be stated the Customs aerodrome or aerodromes at which it is intended to land.

These documents, when signed and stamped by the Customs Officer, constitute the clearance.

On landing at any Customs aerodrome from abroad, the pilot is required to make a report to the Customs Officer, produce the journey log book, manifest and declaration of cargo properly cleared at departure, and to land all passengers for examination of baggage. Unloading of goods may not be commenced until this report has been made and the authority of the Customs Officer obtained.

Pilots' Licences

A.N.D. 11, Paras. 82 *et seq.*

Licences for pilots of flying machines are of two kinds —the "A" licence, which is required by a pilot of a private machine, and the "B" licence, which is necessary before a pilot may fly a machine for hire and reward.

Licences may be obtained at any time, there being no fixed periods or places at which tests or examinations are to be undertaken.

"A" licences remain valid for twelve months and are renewable. The fee payable is 5s., but a further £1 1s. is payable if an official medical examination is needed and another £1 1s. if an official flying test is required. Proofs of competency, medical fitness, and recent flying experience are called for. These requirements are usually met by submitting a certificate as to competency, obtained from the Royal Aero Club, and a certificate as to medical fitness made out on C.A. Form 61 by a duly qualified medical practitioner. Three hours solo flying experience during the preceding twelve months is required before such a licence is issued or renewed.

"B" licences remain valid in the case of males for six months and in the case of females for four months, and are renewable. The fees payable are 5s. for the licence, 5s. for a technical examination, £3 3s. for an official medical examination (10s. 6d. if the medical examination is for renewal), and £10 for an official flying test (if required).

Proofs of competency, medical fitness, and recent flying experience are called for. With regard to competency, the applicant must be possessed

of an "A" licence or undergo the tests required in that case, and, further, undergo the following tests—

A left-hand and right-hand spin.

Two cross-country or oversea flights of at least 200 miles each, during one of which a height of at least 6,500 ft. above the point of departure must be maintained for at least one hour, and including two landings (at points fixed beforehand by the examiners) and terminating with a landing at the point of departure.

A night flight of at least 30 minutes made between two hours after sunset and two hours before sunrise at a height of at least 1,500 ft. above the ground.

A cross-country or oversea flight of at least 200 miles with an examiner on board, and including three forced landings at points selected by the examiner.

General flying for about half-an-hour with an examiner on board and including five landings.

For the two latter tests the flying machine is provided by the Secretary of State.

The technical examination is designed to elicit that the candidate has a satisfactory knowledge of the general construction, functioning and assembly of the aircraft and aero-engines concerned, of his knowledge of rules as to lights and signals, general and special rules for air traffic, and elementary meteorology.

With regard to medical fitness, special examinations are conducted by specially appointed medical officers under the authority of the Secretary of State, and it is to be noted that this medical examination must be undergone before a licence is renewed, after illness or accident, or when a licence holder has performed a total of 125 hours flying as a pilot within any period of 30 consecutive days.

Flying experience amounting to 100 hours as pilot in sole charge of a flying machine, including at least 30 landings, during the preceding two years is required before such a licence is issued. For renewal it is necessary to produce proof of reasonable flying experience during the preceding six months.

Navigators' Licences

Navigators' licences are of two kinds, known as first class and second class. The applicant for a second class licence is required to be competent in the theory and practice of the calculation of course and distance, the reading of maps and charts, compasses, flight by dead reckoning, navigation by radiogoniometry, international air legislation, signalling, and meteorology. In addition he is required to have had at least two years' air experience during which he must have spent at least 300 hours as an operative member of the crew of an aircraft in flight.

A.N.D. 11, Para. 108

The applicant for a first class licence is required to have a more advanced knowledge of the subjects already indicated, and also of tides and astronomical navigation. In addition, he must have had four years air experience during which he must have spent at least 600 hours as an operative member of the crew of an aircraft in flight, including 100 hours navigating in the air and not less than 15 hours night flying.

A.N.D. 11, Paras. 88 & 92

In both cases a medical examination, to the same extent and under the same conditions as apply to class "B" pilots' licences, is required to be undergone before the issue or renewal of a navigator's licence.

These licences remain valid, in the case of males, six months, in the case of females, four months, and are renewable. The fees payable are 5s. for the licence, £3 3s. for an official medical examination (10s. 6d. if the medical examination is for renewal), and, for technical examination, £5 5s. in the case of first class and £2 2s. in the case of second class licences.

The technical examinations in question take place in London usually about March and October each year.

Ground Engineers' Licences

Licences are issued to competent persons for the purpose of inspecting and certifying aircraft and aero-engines as safe for flight, and inspecting and certifying any repairs or replacements that may be made. These are known as ground engineers' licences and are classified in five categories—

A.N. Order, Schedule II, Para. 11

A. Inspection of aircraft before flight.
B. Inspection of aircraft after overhaul.
C. Inspection of aero-engines before flight.
D. Inspection of aero-engines after overhaul.
X. Other duties required to be performed under the Order (usually specialist duties, such as instrument repair and calibration, magneto overhaul and test, parachute packing, and so on).

Applicants for these licences are required to be not less than 21 years of age, to have had satisfactory practical experience in the duties for which the particular licence is required, and to pass an examination.

These licences remain valid for one year, can be extended, and are renewable. Where the ground engineer is constantly operative renewed licences can be made valid for two years.

A.N. Order, Schedule IV

The fees payable are—

	£	s.	d.
(*a*) For the issue of a licence—			
In one category	1	1	–
For each additional category		10	–
(*b*) For the extension of an existing licence—			
In a different category from that already held	1	1	–
In the same category as that already held			
if by examination		10	–
if without examination		5	–
(*c*) For the renewal of a licence			
If by examination	1	1	–
If without examination		10	–

The examinations, which are oral, are held in London weekly, in Croydon monthly, and in Manchester, Bristol, and Glasgow at three-monthly intervals.

The qualifications required can be considered under the two headings, experience and knowledge.

The experience that is taken as satisfactory varies with the particular kind of licence required. Thus, for example, experience over a greater length of time may be required in the case of an "A" licence than in that of an "X" licence for parachute packing, whilst a still longer period might be required in the case of an "X" licence for instrument repair and calibration. For the main licences in respect of aircraft or engines, it can be taken that a minimum period of two years' practical experience will be necessary.

The knowledge required is likewise related to the particular kind of licence in question. Thus an applicant for an "A" licence is examined on the rigging and maintenance of aircraft and flying instruments; the applicant for a "C" licence on the daily maintenance and top overhaul of

aero-engines and all instruments and equipment related thereto in the aircraft; the applicant for a "B" or "D" licence is examined on the construction of the complete aircraft or engine respectively from raw material to finished product, including workshop processes, heat treatments, and, in the case of the "D" category, engine testing.

A syllabus of the examination is issued to each applicant showing the subjects dealt with in each separate category, and it will be seen therein that for all categories a knowledge of the Air Navigation Order and Directions is required. This is important from the point of view of the duties and responsibilities to be undertaken by ground engineers. An "A" licence authorizes its holder to certify as safe for flight the aircraft named in his licence and to replace parts or components which have already been approved and require assembly only, but it does not permit him to certify any repair work involving workshop processes on the same machine; whilst a "B" licence holder, though authorized to certify such repair work, or even the complete construction of the machine, is not permitted to certify it as safe for flight. In the same sense, a "D" licence holder can certify the complete overhaul and testing of an aero-engine but no one who is not the holder of a "C" licence can certify that the engine is properly installed and functioning correctly in an aircraft and is safe for flight.

Ground engineers must never issue certificates unless their licences clearly cover the matériel in question. Thus a person who holds an "A" licence valid for an aircraft but excluding compass, turn indicator, and electrical services, should not "sign out" a machine in respect of any flight for which these are compulsory.

Being in a position of trust, the ground engineer is frequently appealed to by owners for guidance as to the regulations. In any case, he himself must know the steps that must be taken to ensure the embodiment of compulsory modifications and the use of nothing but approved materials, the equipment and instruments that must be fitted in varying conditions of flight, the kinds of log books that must be carried, the kinds of certificates that must be issued by him, and other matters that are all additional to his "trade" knowledge. It is, therefore, clear that a knowledge of the Order and Directions is imperative in so far as they are concerned with ground engineering, inspection and conditions of flight.

Conclusion

These then are the main points in the law relating to civil aviation. It is not, however, to be taken that these constitute a complete statement in the matter, but it is felt that the grouping, arranging and wording adopted here are altogether suitable as an explanation or as a reminder to the reader.

There are other points which have not been dealt with because the circumstances in which they arise are infrequent. For example, the use of wireless on aircraft and the compulsory equipment that is required for making the prescribed signals when night flying or when inadvertently flying over a prohibited area. The use of wireless apparatus on aircraft is highly specialized, and is, in fact, a complete subject in itself, whilst the signalling equipment mentioned varies with the circumstances of the case.

This statement on the law relating to civil aviation might have been concluded with a list of "Don'ts" addressed to pilots, ground engineers, or operators generally. Perhaps, however, this is best left to the reader and he or she, whether engaged as pilot or ground engineer, is strongly urged to study the sections herein dealing with the activities in which he or she may be engaged and to construct such a list of "Don'ts" for himself.

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